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ABSTRACT

Historically, few women pursue studies or careers in science. In an effort to determine factors that relate to a scientific career choice, this research examines differences between sexes and among majors in 180 males and females in biological, physical science, and nonscience college majors. Nonscience majors mostly included female language students and male business students. The variables of spatial ability, mathematical ability, Jungian personality type, and masculinity and femininity were measured through a series of tests. The data indicate among other findings that males preferred to make decisions based on logical analysis and females based on personal values; science majors had higher mathematics scores than nonscience majors mostly due to the scores of physical science majors; no difference existed in the mathematics scores of biological and nonscience majors; science majors had the scientific personality and a positive attitude toward science; nonscience majors had the nonscientific personality and a negative attitude; males, and female physical science majors had masculine characteristics; all female nonscience majors had feminine characteristics; and female biological majors were predominantly feminine. (DC)

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INTRODUCTION

Historically the number of women in science has been low. Even now, despite dramatic increases, recent figures indicate that in 1979 women earned only 10.6% of the doctoral degrees in the physical sciences and 23.4% in the life sciences (Vetter, 1981).

These low numbers have led researchers to examine a number of possible explainations. One explaination is that women lack the cognitive prerequisites of mathematical and spatial ability. Another explaination is that the scientific disciplines may require a personality type more often found among males than females. In particular it may be necessary for women in science to exhibit characteristics which are stereotypically masculine rather than feminine. A third explaination which would affect the choice of a scientific career is that women hold more negative attitudes toward science and do not view it as a suitable career choice.

This investigation examines these factors to determine which, if any, are related to the choice of a scientific career. Of particular interest was whether these factors were equally important in the choice of a biological or physical science career.

REVIEW OF THE LITERATURE

Researchers interested in the personality of the scientist have found them to have a similar set of characteristics regardless of the instruments used to assess personality. Roe (1946, 1952, 1973) found male scientists to be independent, dominant, autonimous, associal and radical.

They preferred order and logical analysis. Cattell (1957), and Erez and Shneorson (1980), describe the scientist in similar terms; reserved, aloof, detached, critical, non-sentimental, taciturn and serious. Welch (1973), describing physics teachers, found that they too exhibited this set of characteristics. Myers (1972) found scientists to be introverted, logical and intuitive with the ability to make firm decisions.

The personality of women scientists reveals a similar pattern with some important differences. Epstein (1973) found women scientists to be less other directed than most women. Andersen (1973) describes the female scientist as emotionally autonimous, having relinquished dependent ties. Spence and Helmreich (1979) found female scientists to be less concerned about the opinion of others than male scientists. It appears that female scientists, in addition to expressing the same personality traits as the male scientists, have characteristics unique to themselves, described as coping mechanisms which Andersen (1973) feels enables women scientists to function in indifferent or hostile environments.

Women in careers that have been traditionally populated by men tend to exhibit more stereotypical masculine traits than women in careers that usually employ women. Spence and Helmreich (1979) found that female scientists had more stereotypical masculine traits than female college students. Peplau (1975) found that women without stereotypically masculine competitive traits were more likely to choose a career in nursing or education than women who exhibited competitive traits. Astin (1969) in a new study of women doctorates found that they possessed stereotypical masculine characteristics in attitudes toward a career, in aggressiveness,

ambition, high self-esteem and competitiveness.

Men in science are more stereotypically masculine than college males (Spence & Helmreich, 1979). Spence and Helmreich attribute this to the scientists' perception of science as a demanding and traditionally masculine field.

Previous research in the area of attitude toward science consistently finds that groups of individuals who were not engaged in scientific studies held less favorable attitudes than those groups who were in some way involved with science (Kelly, 1978; Novick & Duvdvani, 1976; Power, 1981).

Sex differences are also found in attitude toward science. In general males hold more favorable attitudes toward science than females (Kelly, 1978; Kollsche & Newberry, 1971; Lowery, 1976). Within science Novick and Duvdvani (1975) found that a positive attitude toward science was dependent upon high achievement and a special curriculum for females, but not for males.

Spatial ability is a cognitive ability associated with success in science. Roe (1973) found that the scientists she studied had such good spatial ability that it was necessary to construct special tests to assess their ability. Piburn (1980) and Wormack (1979, 1980) found that students with good spatial ability performed better on tests of scientific knowledge.

More specifically, Siemankowski and McKnight (1971) and Talley (1973) examined verbal and spatial ability as it relates to success in college science courses. Students in non-science courses had poorer spatial ability than students in science courses, but the students in physics had better spatial ability than students in any other science discipline. Perhaps of more importance is that Talley (1973) found students with poor spatial ability performed well on the knowledge level in chemistry, but not on the

conceptual level. However, students with good spatial ability performed well on both the knowledge and conceptual level.

Generally females have poorer spatial ability than males (Maccoby, 1968) but not necessarily so. Nash (1975) and Jamison and Signorella (1980) have linked good spatial ability with a masculine or non-traditional sex role orientation.

Another cognitive ability associated with success in science is mathematical ability. Roe (1953) found that ordinary tests of mathematical ability were too easy for her sample of eminent scientists. Naegle and Novack (1975) found that mathematics ability was related to physics achievement. Malone (1977), Perkins (1978) and Rider (1973) found that chemistry achievement was related to overall mathematical ability. Data from the National Science Foundation (1980) indicates that SAT quantitative scores of prospective science majors exceeds those of all other majors except mathematics majors. Carey (1958) and Milton (1957) found that achievement in mathematics was related to a scientific career choice and stereotypical masculine interests.

The research on sex differences is inconclusive. Fenema and Sherman (1978) found sex differences in mathematics at grade eleven in some schools they sampled but not others. Sherman (1980), in a longitudinal study, found no sex differences in her sample of the eighth grade, but by the time they had reached the eleventh grade sex differences favoring males had appeared. Fenema (1974), in a study of sixth through twelveth grade, found sex differences in computational and higher level tasks to be rare, when differences did occur they were small.

HYPOTHESES

The previous research cited led to the hypotheses that science and non-science majors would have different mathematical and spatial ability, attitude toward science and personalities, including stereotypical masculinity and femininity. Within science these factors would distinguish between biological and physical science majors. Sex differences in mathematical and spatial ability and attitude toward science were expected across majors, but not within majors.

DESIGN

The subjects in this study were male and female undergraduates in the biological sciences, physical sciences and non-science majors. There were 180 subjects, 30 in each group. The famle non-science majors were language students. The male non-science majors were primarily business students. Subjects were volunteers who responded to classroom announcements and newspaper advertisements. Each subject was paid $5.00 for their participation.

Subjects were given a battery of tests which required approximately 1½ to 2 hours to complete. All tests were self-paced except for the timed spatial test.

Discriminant analysis and analysis of variance were used to test the hypotheses.

Instruments

Personality was assessed by the Myers-Briggs Type Indicator which is based on the Jungian typologies of extrovert, introvert (EI), sensing, intuitive (SN), thinking, feeling (TF), and judging, perceiving (JP).

Reliabilities for college students for each scale are as follows: (EI), r=.81, (SN), r=.87, (TF), r=.87 and (JP), r=.80 (Myers, 1962).

The (EI) scale measures an individual's preference for focusing on the outerworld of people and things (E), or the inner world of the mind (I). The (SN) scale measures a preference for knowing the world directly through the senses (S) or knowing through a more indirect intuitive process (N). The (TF) scale measures a preference for decision making based on logical analysis (T), or personal values (F). The (JP) scale assesses the preference for coming to a conclusion, ignoring additional data and making an irrevocable choice (J), or a more cautious open minded approach to decision making in which the possibility of new developments always exists (P) (Meyers, 1962).

The Personal Attributes Questionnaire (Spence & Helmreich, 1979) was used to determine stereotypical masculinity and femininity. This measure consists ofthree scales of items believed by college students to be stereotypically characteristic of males and females (Rosenkrantz, Vogel, Bee, Broverman & Broverman, 1968). The scales are masculinity (M), femininity (F), and masculinity-femininity (M-F). The items on the (M) and (F) scale have been percieved as desirable for both sexes, but are found more often among males for the (M) scale or females for the (F) scale. The items on the (M-F) scale are characteristics whose social desirability is perceived to vary for each sex (Spence & Helmreich, 1979). The reliabilities for each scale are (M), r=.85, (F), r=.82, (M-F), r=.78.

Attitude toward science was determined by the subjects' responses to a four item questionnaire; (a) they dislike science and are actively pursuing a career in a non-science field. (b) They are indifferent to

science. (c) They like science but are considering other careers. (d) They like science and are planning a career in science.

The responses were scored 0 through 3 from least positive to most positive. These questions were chosen for two reasons. First, I was not interested in a broad based attitude toward science, but in attitude toward science in terms of its desirability as a career. Second, most attitude toward science questionnaires contain a cluster of items which asks to what extent individuals like science and whether or not science is seen as a desirable career for themselves.

To measure spatial ability, Spatial Rotations, S2, from the Kit of Factor Referenced Tests was used (Ekstrom, French, Harman & Derman, 1976). Subjects were allowed six minutes for each of a two part test. The reported reliabilities of this instrument are low for college females. Consequently a reliability test was performed on 504 students at the same university from which this sample was drawn. The alpha obtained was .90 for males and .84 for females.

Scores from the Scholatic Aptitude Test, quantatative section, were used as a measure of mathematical ability. Verbal scores were used as a control for verbal ability. The scores were obtained from university records and were rounded off to the nearest ten.

RESULTS

Discriminant Analysis

In examining differences between males and females with discriminant analysis SAT mathematics scores and stereotypical masculinity (M) were the most important variables. They had canonical discriminant function

coefficients of -.74 for math and .58 for (M) indicating that the differences between males and females was based primarily on these two factors. Males had both higher mathematics and masculinity scores. Other variables significant at .05 or less which contributed to the discriminant function equation were the (M-F) scale of the Personal Attributes Questionnaire, the (TF) and (JP) scales of the Myers-Briggs Type Indicator and SAT verbal scores. A comparison of predicted group membership to actual group membership indicates that 72.2% of the females were correctly classified and 75.0% of the males were correctly classified on the basis of the significant variables. The group centroid for males was -.65 and for females .65. The difference was significant at the $<.01$ level.

Science and non-science majors were distinguishable primarily on the basis of attitude which had a canonical discriminant function correlation of .95. Science majors had a more positive attitude toward science than non-science majors. Mathematics score, (M) score and the (JP), (SN) and (TF) scales of the Myers-Briggs Type Indicator were also significant discriminating variables at the $<.05$ level.

A comparison of predicted group membership to actual group membership indicates that 90.2% of all science majors and 75.9% of all non-science majors were correctly classified. The group centroid for science majors was .54 and -.11 for non-science majors ($p<.01$).

Biological, physical science and non-science majors were distinguishable on the basis of attitude and general academic aptitude. Two significant functions were generated. Attitude had a canonical discriminant function coefficient of -.95 on function one. On function two, mathematics and verbal SAT scores had coefficients of -1.34 and -.95 respectively.

Other discriminating variables included the (JP), (SN) and (TF) scales, (M) score and spatial ability.

A comparison of actual group membership to predicted group membership indicates that 63.6% of the biological science majors, 64.3% of the physical science majors and 73.7% of the non-science majors were correctly classified. Misclassified biological science majors were classified as physical science majors and misclassified physical science majors were classified as biological science majors. Only 9.5% of the biological majors and 7.1% of the physical science majors were misclassified as non-science majors. Misclassified non-science majors were equally distributed between the biological and physical science majors.

The group centroid for biological science majors was -.54, for physical science majors -.53 and 1.07 for non-science majors on function one. On function two the group centroids were .36 for biological science majors, -.37 for physical science majors and, .003 for non-science majors. The centroids of biological and physical science majors were not significantly different. Other comparisons were significant at $p<.01$.

Male and female science and non-science majors were distinguishable primarily on the basis of attitude, SAT math and masculinity. Attitude had a canonical discriminant function coefficient of -.89 on the first function. SAT math had a coefficient of -.52 on the second significant function. Other discriminating variables were the (F) and (M-F) scales of the Personal Attributes Questionnaire and the (JP), (TF), and (SN) scales of the Myers-Briggs Type Indicator.

Seventy-one and seven tenth per cent of the female non-science majors, 74.1% of the female non-science majors, 63.8% of the male science majors

and 53.3% of the male non-science majors were correctly classified. Misclassifications were in the categories of the opposite sex. Few misclassifications were by major. Group centroids are in Table I. All groups were significantly different from each other at $p<.01$.

TABLE I

GROUP CENTROIDS FOR MALE AND FEMALE SCIENCE AND NON SCIENCE MAJORS

	Function 1	Function 2
Female Science	-.45	.68
Male Science	-.60	-.49
Female Non Science	1.37	.50
Male Non Science	.74	-.89

Male and female biological, physical science and non science majors were distinguishable primarily on the basis of attitude and academic ability. Attitude had a canonical discriminant function coefficient of -.88 on the first significant function. On function two SAT math had a coefficient of -.87 and SAT verbal a coefficient of .63. Other variables which contributed to the discriminant function were the (M), (F), and (M-F) scales of the Personal Attributes Questionnaire and the (TF) and (JP) scales of the Myers-Briggs Type Indicator. A greater number of females were correctly classified on the basis of these variables than males (Table 2).

Table 2

PERCENTAGE OF CORRECT CLASSIFICATION BY SEX AND MAJOR

	%
Female Biological Science	69.2
Female Physical Science	66.7
Female Non Science	66.7
Male Biological Science	35.7
Male Physical Science	48.3
Male Non Science	53.3

Group centroids are in Table 3. All groups were significantly different from each other at $p < .01$ except female physical science majors and male biological science majors ($p < .05$). There was no significant difference between female biological and physical science majors.

TABLE 3

GROUP CENTROIDS BY MAJOR AND SEX

	Function 1	Function 2
Female Biological Science	-.16	.88
Female Physical Science	-.64	.54
Female Non Science	1.40	.40
Male Biological Science	-.78	-.40
Male Physical Science	-.46	-.71
Male Non Science	.64	-.90

Analysis of Variance

Two way analysis of variance indicated that there were very few differences which could be attributed to a single variable (Table 4).

TABLE 4

TWO-WAY ANALYSIS OF VARIANCE

MBTI		SS	df	MS	F
TF	Main Effect	7620.33	3	2540.07	6.23*
	Sex	5205.69	1	5205.69	12.76*
	Major	2414.53	2	1207.27	2.96
	Interaction	268.05	2	134.23	.33
S2	Main Effect	1498.24	3	374.56	3.69+
	Sex	49.77	1	49.77	.49
	Major	1198.62	2	399.54	3.94+
	Interaction	48.97	2	16.32	.92
Att.	Main Effect	105.17	3	26.29	48.18*
	Sex	.86	1	.86	1.57
	Major	104.99	2	34.99	64.12*
	Interaction	1.71	2	.57	.36
Math	Main Effect	303879.88	3	101293.25	6.82*
	Sex	208284.00	1	202284.00	14.03*
	Major	95595.88	2	47797.94	3.22+
	Interaction	2951.43	2	1475.72	.10

*p<.001

+p<.05

Post hoc analysis indicated that both science majors had higher spatial and attitude scores than non science majors, but there was no difference between science majors. Physical science majors had higher mathematics scores than non science and biological science majors. There was no difference in math scores between biological and non science majors.

DISCUSSION AND CONCLUSIONS

The differences seen among groups in the discriminant analysis which do not appear in the analysis of variance are due to the nature of the analysis. In discriminant analysis we see the cumulative effect of many small differences that taken together contribute to the overall differences in the groups. In the analysis of variance we see the effect of single variables to distinguish among groups.

There were few sex differences. Males had higher math scores than females and preferred the logical analytical approach to decision making. Females preferred to base their decisions on personal values.

Science majors had higher math scores than non-science majors. This is attributable to the strength of the scores of physical science majors. Mathematics, at least in this sample, is not functioning as a filtering mechanism into biology.

Both science majors had better attitudes toward science and better spatial ability than non science majors. However, spatial ability was not an important factor in the discriminant analysis.

As expected personality was working as a filtering mechanism. All science majors had the intuitive, thinking, judging personality found in scientists by the Myers-Briggs Type Indicator. Non science majors ex-

hibited the opposite personality type. They were sensing, feeling and perceiving. However many male non science majors preferred the thinking mode over the feeling mode. This suggests that it is a combination of personality factors that influence career choice.

Female science majors were found to have more stereotypical masculine traits than female non science majors. Within science the female physical science majors exhibited more stereotypical masculine traits than biological science majors. The biological sciences may be perceived by women as less masculine and more appropriate to female sex roles than the physical sciences. However the higher masculinity scores of the female physical science majors should not be taken to mean that these women perceive themselves as masculine. One can have the traits associated with masculinity such as independence, dominance, emotional invulnerability and competitiveness without viewing oneself as masculine. It may be the case that women who choose the physical sciences are exhibiting situationally effective characteristics which allows them to successfully function in a traditionally male career. Table 5 is a summary of the characteristics of the six groups in the study.

TABLE 5

PROFILES OF THE MALE AND FEMALE BIOLOGY, PHYSICAL SCIENCE AND NON-SCIENCE MAJORS

GROUP	STEREOTYPE IDENTIFICATION	PERSONALITY	OUTSTANDING ASPECTS	MATH	VERBAL	ATTITUDE
Female Biology	More feminine than masculine	NTJ	None	Good	Good	Like
Female Physical Science	Masculine	NTJ	Judging & Strongly Thinking	Excellent	Good	Like
Female Non-Science	Feminine	SFP	Strongly Feeling	Poor	Good	Dislike
Male Biology	Masculine	NTJ	None	Good	Good	Like
Male Physical Science	Masculine	NTJ	Strongly Thinking	Excellent	Good	Like
Male Non-Science	Masculine	STP	Thinking	Good	Good	Dislike

Caution must be exercised when generalizing from this study because it consisted of volunteers. Given that volunteers tend to be more sociable than non volunteers this sample, particularly the science majors, may not be representative. In general scientists have been described as asocial. The voluntary nature of the sample may be the reason why the expected differences in introversion for the science majors and extroversion for the non science majors were not found. On the other hand all other expected personality variables were found in the science and non science groups.

The unexpectedly low math scores of the biology majors seems to argue in favor of representativeness since volunteers score higher than non volunteers on tests of aptitude. One would not expect a large group of individuals to volunteer if they felt they were doing poorly in mathematics.

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